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Fall Diets of Red-breasted Merganser (Mergus serrator) and Walleye (Sander vitreus) in Sandusky Bay and Adjacent Waters of Western Lake Erie

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Abstract.—Although published studies indicate the contrary, there is concern among many sport anglers that migrating red-breasted mergansers (*Mergus serrator*) and other waterbirds pose a competitive threat to sport fish species such as walleye (*Sander vitreus*) in Lake Erie. We quantified the diet of autumn-migrant mergansers and walleye during 1998–2000 in Sandusky Bay and adjacent waters of western Lake Erie. We hypothesized that the diets of both predators would be similar in species composition, but because of different foraging ecologies their diets would differ markedly in size of prey consumed. In addition to predator samples, we used trawl data from the same general area as an index of prey availability. We found that mergansers fed almost exclusively on fish (nine species). Gizzard shad (*Dorosoma cepedianum*), emerald shiner (*Notropis atherinoides*) and round goby (*Neogobius melanostomus*) were consumed in the greatest numbers, most frequently and comprised the greatest biomass. Walleye fed exclusively on fish: gizzard shad, alewife (*Alosa psuedoharengus*) and emerald shiner were consumed in the greatest numbers, most frequently and comprised the greatest biomass. Diet overlap between mergansers and walleye was 67% by weight and 66% by species frequency. Mean total lengths of gizzard shad, emerald shiner and round goby found in walleye stomachs exceeded those captured in trawls by 47%, on average. Mean total lengths of gizzard shad, emerald shiner and round goby were greater in walleye stomachs than in merganser stomachs. Mean total lengths of emerald shiner and round goby were less in merganser stomachs than in trawls. Our results suggest that although the diets of walleye and mergansers overlapped considerably, mergansers generally consumed smaller fish than walleye. Given the abundance and diversity of prey species available, and the transient nature of mergansers on Lake Erie during migration, we conclude that competition for food between these species is minimal.

Introduction

In North America, red-breasted mergansers (*Mergus serrator*, hereafter: mergansers) feed in a variety of water bodies, including the ocean and associated bays, estuaries, large rivers and lakes. Western Lake Erie provides an important rest stop for migrating mergansers because of its location (Bellrose, 1976) and abundant prey-fish population (Hartman and Margraf, 1992; Deller *et al.*, 2003). As many as 210,000 mergansers migrate through Lake

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Erie annually (Peterjohn, 1989), and many of these birds stage for several weeks or more in western Lake Erie during the spring and autumn (M. Shieldcastle, Ohio Department of Natural Resources [ODNR], pers. comm.). However, little is known about the feeding ecology of migrating mergansers staging in this region.

Given the importance of sport fisheries to the economy of the Great Lakes region (Talhelm, 1988), potential foraging competition between piscivorous waterbirds (*e.g.*, mergansers and double-crested cormorants, *Phalacrocorax auritus* [Bur *et al.*, 1999; Madenjian and Gabrey, 1995]) and sport fish is a concern. Lake Erie sustains a rather large and diverse predatory fish community, including walleye (*Sander vitreus*), yellow perch (*Perca flavescens*) and other species (Nepszy, 1999). In western Lake Erie, Hartman and Margraf (1992) calculated that walleye consumed, on average, 88,200 metric tons of prey fish during each growing season (May through Nov.) from 1986 through 1988. In comparison, Madenjian and Gabrey (1995), using a bioenergetics model, estimated that piscivorous waterbirds on Lake Erie consumed 13,368 metric tons of fish per year. Of the total tonnage, mergansers ate an estimated 37%, almost twice the quantity estimated as consumed by any other bird species, including double-crested cormorants (Madenjian and Gabrey, 1995). However, there are limited data available on the species, quantities and sizes of the fishes consumed by mergansers on Lake Erie.

Previous authors have described the diet of mergansers as consisting of a wide variety of fish (Cottam and Uhler, 1937; Munro and Clemens, 1939; White, 1957; Cronan and Halla, 1968; Feltham, 1990). Merganser diets have been more closely monitored in Sweden and Great Britain than in North America (Sjöberg, 1985; Feltham, 1990). In the majority of North American studies, conducted primarily along the Atlantic or Pacific coasts, red-breasted mergansers were shown to be opportunistic foragers (White, 1937; Munro and Clemens, 1939; Stott and Olson, 1973; *see* also reviews by Johnsgard, 1975; Bellrose, 1976). Hence, the diets were composed typically of marine and anadromous fish (Cairns, 1998), prey species not indigenous or common to the Great Lakes. Although the winter diet of mergansers from Michigan streams was described by Leonard and Shetter (1936), the diet of mergansers in the Great Lakes region has been poorly documented overall.

Despite the conclusions of Madenjian and Gabrey (1995), there is concern among many sport anglers that migrating mergansers and other waterbirds pose a competitive threat to sport fish species, particularly walleye in Lake Erie. Madenjian and Gabrey's (1995) estimate of merganser and cormorant prey consumption in their bioenergetics model was based on diet from locations other than Lake Erie because data for Lake Erie waterbird diets were not available at the time of their study. Both walleye and yellow perch are piscivorous and consume similar prey fish species to that of mergansers and double-crested cormorants (Knight *et al.*, 1984; Hartman and Margraf, 1992). Therefore, additional information on the respective diets of mergansers and walleye in Lake Erie, notably selection of prey species and prey lengths, would be useful in refining these bioenergetics models.

The purpose of our study was to provide insight on the potential for direct prey and resource partitioning between mergansers and walleye in terms of prey species and size. We hypothesized that the diets of both predators would be similar in species composition, but because of different foraging ecologies and feeding morphologies, would contrast markedly in size of prey consumed. To test this hypothesis we compared lengths of some prey species found in the stomachs of walleye and autumn migrant mergansers in Sandusky Bay and from trawl catches in adjacent waters of western Lake Erie. We also quantified overlap in the diets of walleye and mergansers.

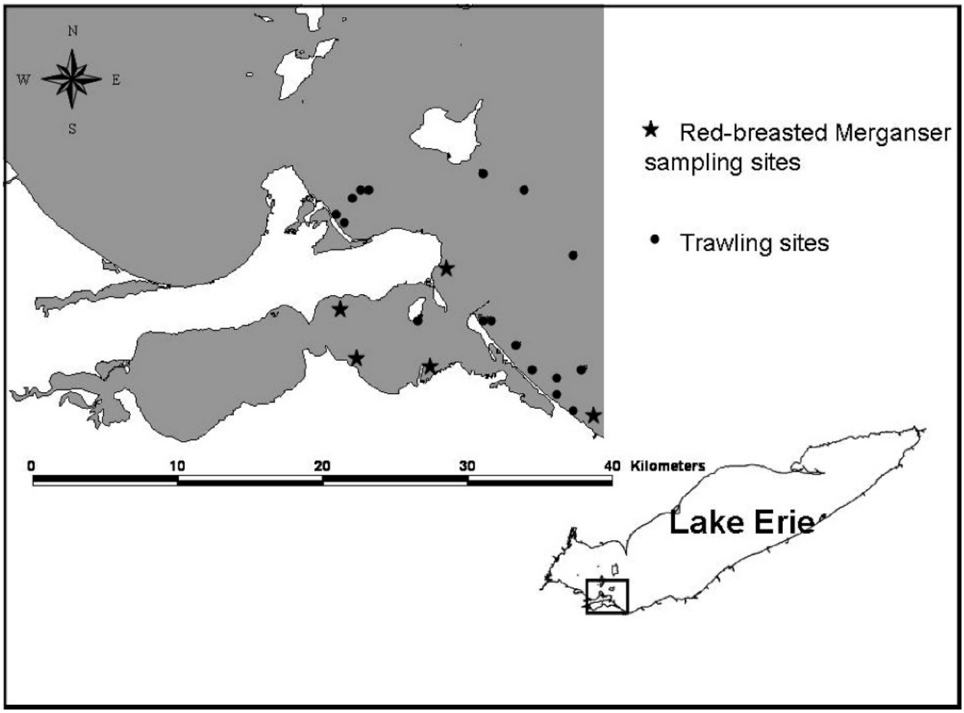


FIG. 1.—Sampling locations in Sandusky Bay and western Lake Erie

METHODS

Study area.—We conducted our study in Sandusky Bay and adjacent waters of western Lake Erie (Fig. 1). The area is within a commercial shipping channel and is popular for sport anglers. Average water depth was approximately 4 m with a maximal depth of about 9 m. Common fish species in the study area included white perch (*Morone americana*), gizzard shad (*Dorosoma cepedianum*), emerald shiners (*Notropis atherinoides*), round gobies (*Neogobius melanostomus*), alewife (*Alosa pseudoharengus*), bluegill (*Lepomis macrochirus*), yellow perch and walleye. Zebra mussels (*Dreissena polymorpha*) and quagga mussels (*D. bugensis*) were abundant benthic macroinvertebrates. Shoreline area was mostly agricultural (row crops) and urban.

Collection of mergansers and stomach analysis.—We collected mergansers during Nov. to mid-Dec., 1998–2000. Mergansers were obtained from the daily bag of duck hunters who participated in the study, and from researchers from the U.S. Geological Survey (USGS) and the U.S. Department of Agriculture's Wildlife Services. All birds were shot with non-toxic steel shot from a 12-gauge shotgun. At the time of collection, each bird was individually marked with a unique identification tag number. To reduce digestion, isopropyl alcohol was injected into the esophagus and stomach of each bird within 1 h after collection. All specimens were returned to the laboratory, where morphological data were recorded and stomach contents were examined.

Specimens were weighed and measured for overall length (from tip of bill to end of tail) and wing length (from right wing tip to axillary). Sex and maturity were determined for each individual by gonadal development. Each esophagus and stomach was removed, placed in a labeled plastic bag, chilled on ice and processed within 48 h. We used an analysis of variance (ANOVA) (critical level of $\alpha = 0.05$; SAS, 2001) to evaluate potential differences between sexes in mean body length and body weight of mergansers. Sex, year collected and interaction between sex and year collected were the independent variables in the model, and mean body length and mean weight were the dependent variables.

Fishes in mergansers' stomachs were identified to species from whole specimens, when available, or fragments such as scales, otoliths and other diagnostic bones. For each prey species we calculated the total numerical abundance in all stomachs, as well as the number of stomachs containing each species. Whole fish were measured to the nearest mm of total length. For partially digested fish, equations from Knight *et al.* (1984) were used to convert standard and backbone lengths to total lengths. We estimated wet weight of fishes, at the time of ingestion, using wet weight-total length regressions (Hartman, 1989; M. Kershner, The Ohio State University, unpubl. data; R. Knight, ODNR, Sandusky, Ohio, unpubl. data).

Collection of prey fishes from bottom trawls.—We estimated prey fish abundance from 39 trawl catches in the same general area and time during which mergansers were collected (Fig. 1). Trawl data were obtained as part of annual autumn fish-assessment programs in western Lake Erie conducted by USGS and ODNR. Trawl tows at each station in Sandusky Bay and Lake Erie proper were 10 min in duration and were conducted during Sep.–Oct. 1998–2000. The trawl nets were either a 10-m headrope bottom trawl (ODNR) or 7.9-m headrope bottom trawl (USGS). Boat speed was maintained at approximately 3.5 km/h during trawls. Actual height of the trawls during operations was between 1 m and 2 m. Although trawling operations were conducted with bottom trawls, depths rarely exceeded 4 m. We assumed that the sizes of the species caught in the trawls were representative of the local populations that were available to mergansers. Trawl catches were sorted from each tow and enumerated by species and age groups (young-of-the-year and age-1-and-older). Approximately 30 fish of each species were randomly selected from each age group within a trawl catch, and each fish was measured for total length by age group.

Collection of walleye.—Walleye were collected from gill nets set in the study area during Oct. 1998–2000. Walleye were collected from 12 gill net sets in 1998 (ODNR, 1999), 12 gill net sets in 1999 (ODNR, 2000) and 16 gill net sets in 2000 (ODNR, 2001). Specimens were measured for total length and weight was calculated from a length-weight regression equation (ODNR, 2001). Stomachs were removed and prey were extracted from stomachs and identified the same day in the laboratory. Fishes found in walleye stomachs were identified to species from whole and partially digested specimens and from fragments (*e.g.*, scales, otoliths and other diagnostic bones). As in the merganser stomachs, we scored each prey species relative to numerical abundance and frequency of occurrence. Total lengths of whole fish found in stomachs were measured to the nearest mm of total length. For partially digested fish we used equations from Knight *et al.* (1984) to convert standard and backbone lengths to total lengths. We estimated wet weight of fishes, at the time of ingestion, using wet weight-total length regressions (Knight *et al.*, 1984).

Statistical analyses.—We used ANOVA (critical level: $\alpha = 0.05$; SAS 2003) to test for differences in mean prey length between male and female mergansers. For gizzard shad, emerald shiner and round goby, we conducted separate ANOVAs in which mean total length of the fish species consumed was the dependent variable and sex of the mergansers was the independent variable in the model. Stomach data from all three years of the study were combined in this analysis due to small annual sample sizes.

TABLE 1.—Number, mean body lengths and mean body weights of red-breasted mergansers collected from Sandusky Bay and adjacent waters of western Lake Erie during Oct.–Dec. 1998–2000

	Males					Females				
		Body length (mm)		Body weight (g)			Body length (mm)		Body weight (g)	
Year	N	Mean	SE	Mean	SE	N	Mean	SE	Mean	SE
1998	12	572	3.9	1195	24.3	31	522	5.7	998	23.3
1999	34	586	20.4	1040	42.0	20	521	6.0	925	26.9
2000	28	574	3.3	1130	19.5	19	513	6.0	934	26.7
All years	74	581	9.4	1100	22.0	70	520	3.5	960	15.1

We used ANOVAs to determine if mean total length of prey fish collected in trawls differed from mean total lengths of fish ingested by mergansers or walleyes. Data from all three study years were combined in this analysis. The independent variables were the source in which the fish were found (*i.e.*, walleye or merganser stomach or trawl, df = 2), year collected (df = 2) and the interaction between source and year. In preliminary analyses, we found data were sufficient to conduct these analyses on only three of the species collected in the stomachs and trawls (gizzard shad, emerald shiner and round goby). Separate analyses were performed for each of these three species of prey fish. We used Tukey's Honest Significant Difference test (HSD) for pairwise comparisons of the least-square means for instances in which the source effect was significant in the ANOVA.

Next we tested if the proportions of specific length groups of the prey species were different in the trawl catches than in merganser stomachs or walleye stomachs. For each of these three species, we combined the specimens we obtained in the trawls and stomachs and divided the range of the total lengths of the specimens collected into groups of 10-mm increments. Proportions for each prey species in each length group were calculated for each merganser stomach, for each walleye stomach and for each trawl catch. We calculated separate 95% confidence intervals of the means for each proportion by length group for fish found in trawl catches and for fish found in merganser and walleye stomachs. We then compared the confidence intervals, for each length group to determine if the proportion consumed by mergansers was different than the proportion collected in the trawls. This procedure was repeated for each of the three prey fish species identified above.

Finally, we calculated an index of overlap (α) (Schoener, 1970) between mergansers and walleye for three measures of diet: proportion by wet weight, proportion of total numbers of prey and frequency of occurrence according to Wallace (1981). Diet overlap was considered significant when $\alpha > 0.6$ (Wallace, 1981 and references therein). We did not calculate a Spearman rank correlation to determine if there was a significant difference in the diets (Wallace, 1981) because there was a large proportion of ties, particularly for prey taxa that were not consumed by both mergansers and walleye. Unidentified Clupeidae found in walleye stomachs were categorized as gizzard shad because: (1) alewife and gizzard shad are the only clupeids routinely found in the study area and (2) mergansers did not consume alewife. Therefore, our estimate of α was conservative.

RESULTS

Mergansers.—Sex was determined in 144 of the 147 mergansers collected (Table 1). Data on morphological measurements for mergansers are included because recent morphological data is limited. Overall, males (n = 74) were heavier than females (n = 70), averaging

TABLE 2.—Prey species found in the stomachs of red-breasted mergansers collected from Sandusky Bay and adjacent waters of western Lake Erie during Oct.–Dec., 1998–2000

Species	N	Relative abundance (%)	Frequency of occurrence (%)	Relative biomass (%)	Total length (mm)		
					Mean	SE	Range
gizzard shad *Dorosoma cepedianum*	98	49.1	69.7	85.7	102.7	2.1	62–159
emerald shiner *Notropis atherinoides*	64	27.5	21.2	5.5	53.4	1.1	36–83
quillback *Carpiodes cyprinus*	1	0.4	1.5	1.7	135	–	–
rock bass *Ambloplites rupestris*	1	0.4	1.5	0.2	59	–	–
bluegill *Lepomis macrochirus*	10	3.7	1.5	0.7	42.7	1.6	35–50
white crappie *Pomoxis annularis*	1	0.4	1.5	0.2	66	–	–
white perch *Morone americana*	1	0.7	1.5	1	100	–	–
yellow perch *Perca flavescens*	1	0.4	1.5	0.5	87	–	–
round goby *Neogobius melanostomus*	27	12.1	16.7	5.1	50.0	3.3	23–104
Zebra mussel *Dreissena polymorpha*	1	<0.1	0.1	<0.1	–	–	–

1.1 kg vs. 0.9 kg ($F_{1,\ 144}$ = 143.2, P < 0.0001, HSD test: P < 0.05). The interaction between study year and sex on body weight was not significant ($F_{2,\ 144}$ = 0.1, P = 0.92). Males were longer than females, averaging 581 mm compared with 520 mm ($F_{1,\ 144}$ = 143.2, P < 0.0001, HSD test: P < 0.05). The mean bill length for males (56.7 mm, SE = 0.4) was significantly greater ($F_{1,\ 144}$ = 71.7, P <0.0001) than for females (51.5 mm, SE = 0.5). The mean culmen depth for all birds combined was 13.7 mm (SE = 5.9), as there was no significant difference in culmen depth between males and females ($F_{1,\ 144}$ = 2.94, P = 0.09).

No discernable food was found in 54% of the merganser stomachs. Identifiable diet items were virtually all fish, except for one zebra mussel (Table 2). Prey length ranged from 23–159 mm (mean = 78.4 mm, SE = 2.1). We identified nine fish species in the stomachs of mergansers, of which three species accounted for 88.7% of the number of fish consumed and 96.3% of the estimated wet biomass of all prey (Table 2). Young-of-year gizzard shad made up 49.1% of the number of fish recorded, 85.7% of the fish biomass and occurred in

TABLE 3.—Prey taxa found in the stomachs of walleye (n = 247) collected from Sandusky Bay and adjacent waters of western Lake Erie during Sep.–Nov. 1998–2000

Taxon	N	Relative abundance (%)	Frequency of occurrence (%)	Relative biomass (%)	Total length (mm)		
					Mean	SE	Range
Clupeidae	52	1.3	9.5	–	123.4	3.1	96–184
alewife *Alosa psuedoharengus*	1016	24.7	63.9	21.0	97	0.4	52–144
gizzard shad *Dorosoma cepedianum*	2309	56.2	84.6	71.2	109.9	0.4	45–199
emerald shiner *Notropis atherinoides*	645	15.7	42.7	4.7	66.7	0.6	41–141
rainbow smelt *Osmerus mordax*	25	0.6	1.2	0.2	118.4	5.0	49–158
logperch *Percina jenkinsi*	1	0.1	0.4	0.1	53.0	–	53
white perch *Morone americana*	19	0.5	2.5	0.3	72.0	4.0	48–134
yellow perch *Perca flavescens*	5	0.1	1.7	0.4	111.1	17.4	77–167
round goby *Neogobius melanostomus*	40	1.0	8.3	2.2	105.1	4.5	57–187

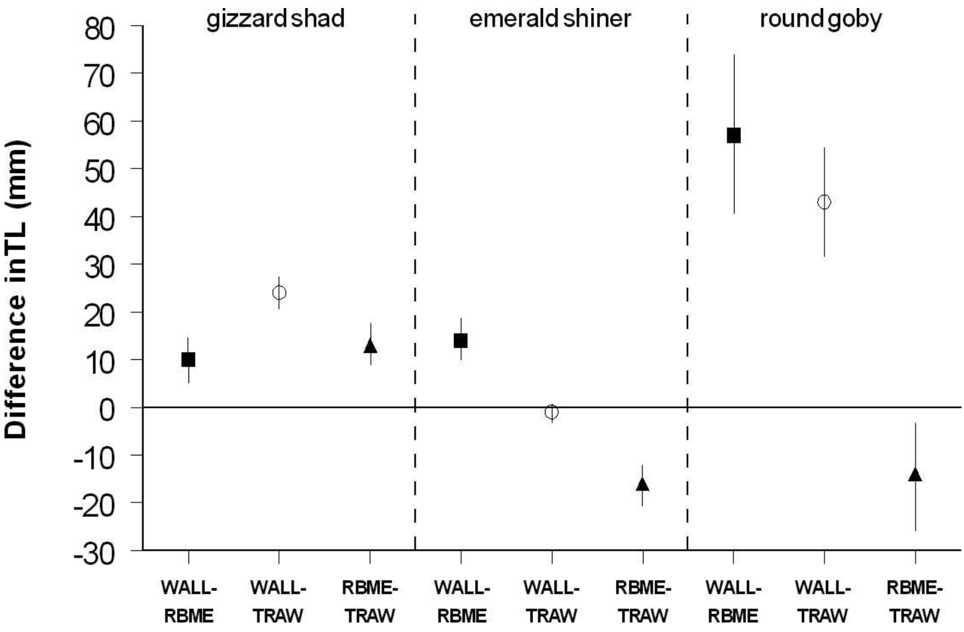


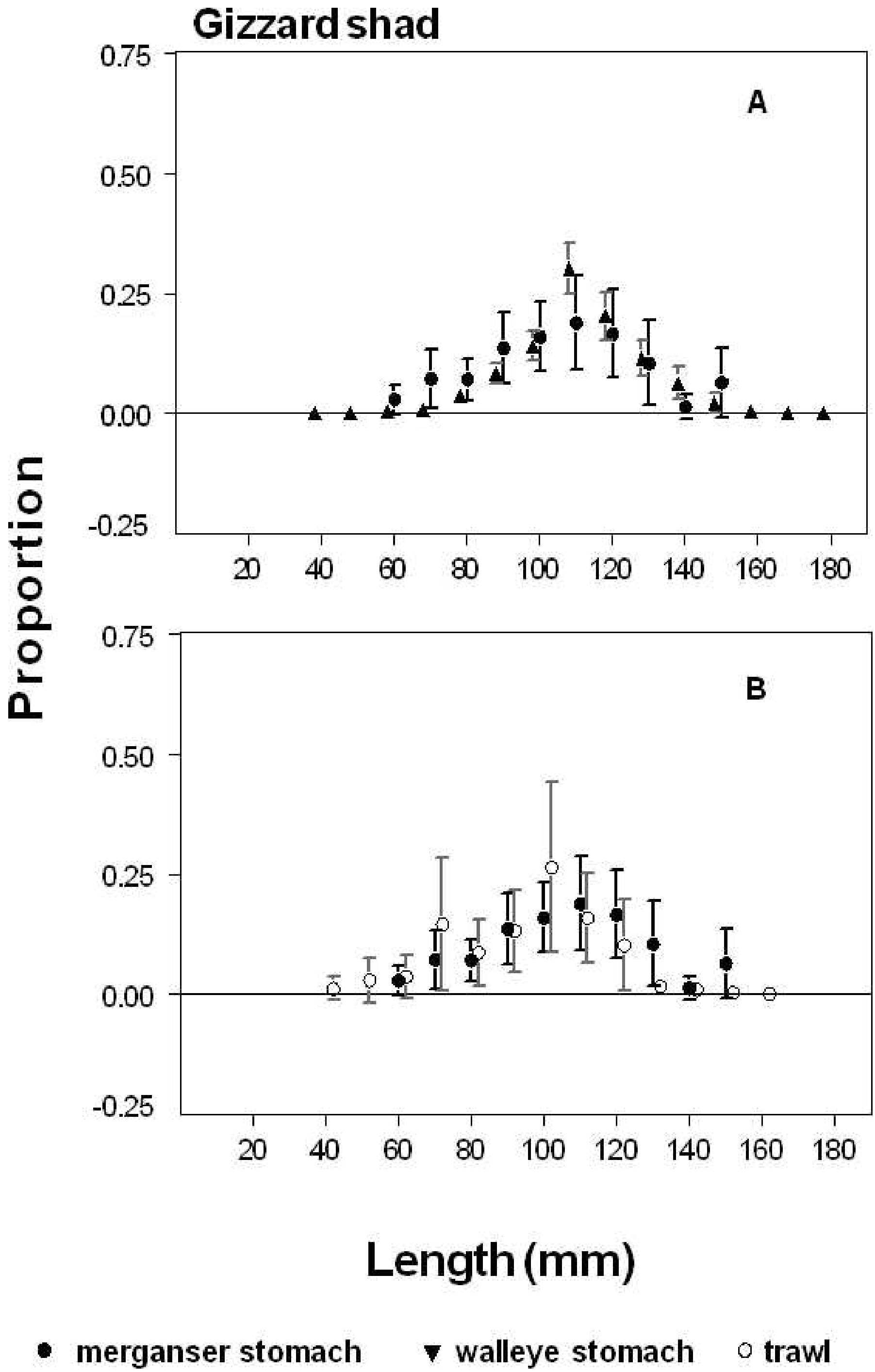
FIG. 2.—Differences (95% confidence interval, HSD test) in least square mean total lengths (TL) of three sources of prey fishes: walleye stomachs (WALL), red-breasted merganser stomachs (RBME) and bottom trawls (TRAW) in western Lake Erie, 1998–2000. Positive values indicate longer TL in the first source of each pair, negative values indicate longer TL in the second source. Intervals that include zero indicate no difference in TL between the two sources

69.7% of the stomachs. Emerald shiner (21.2%) and round goby (16.7%) were the next most frequently eaten prey. Emerald shiner and round goby each occurred in merganser stomachs approximately one-third as frequently as gizzard shad (69.7%).

There was no significant difference in the number of prey fish consumed between sexes (linear regression: $F_{1,\ 54} = 0.4$, $P = 0.54$) or number of prey by species (including only emerald shiner, gizzard shad and round goby in the analysis) consumed between sexes ($F_{5,\ 63} = 1.0$, $P = 0.36$). There were also no differences in the total length of prey fish consumed between sexes ($F_{1.192} = 0.1$, $P = 0.32$) or the total length of prey fish consumed between sexes for maturity ($F_{1,\ 161} = 2.1$, $P = 0.15$).

Walleye.—We collected 241 walleye stomachs all of which contained prey items in stomachs. Walleye total length ranged from 250 mm to 714 mm (mean = 393.0 mm, SE = 5.19) and calculated walleye weight ranged from 130 g to 3261 g (mean = 801.5 g, SE = 32.2). Eight prey taxa, all fish, were identified (Table 3). Prey length ranged from 41 mm to 199 mm (mean = 100.1 mm, SE = 0.4). Gizzard shad was the dominant prey found, accounting for 71% of the wet biomass and more than half of the number of prey items. Gizzard shad, alewife and emerald shiner accounted for 96.9% of the wet biomass and 96.6% of the items found in walleye stomachs. Unlike the merganser stomachs, round goby made up a relatively small proportion and alewife made up a relatively large proportion of the prey items found in the walleye stomachs.

Trawls.—We collected 2193 gizzard shad, emerald shiner and round goby from the trawls. Mean total lengths were 90.0 mm (n = 786, SE = 0.9) for gizzard shad, 70.0 mm (n = 757, SE



Gizzard shad
A
B
Proportion
0.75
0.50
0.25
0.00
-0.25
20
40
60
80
100
120
140
160
180
Length (mm)
merganser stomach
walleye stomach
trawl

= 0.5) for emerald shiner and 65.7 mm (n = 650, SE = 1.0) for round goby. Prey collected in trawls and found in stomachs included young-of-year and yearling-and-older individuals.

There were significant differences among the three sources (merganser stomachs, walleye stomachs and trawls) in the mean total lengths of gizzard shad ($F_{2,\ 1794} = 261.2$, $P < 0.0001$), emerald shiner ($F_{2,\ 1176} = 36.7$, $P < 0.0001$) and round goby ($F_{2,\ 702} = 42.5$, $P < 0.0001$). Gizzard shad, emerald shiner and round goby found in walleye stomachs were longer than those found in merganser stomachs (HSD tests, $P < 0.05$, Fig. 2). Similarly, gizzard shad and round goby found in walleye stomachs were longer than those collected in trawls and gizzard shad found in merganser stomachs were longer than those collected in trawls (HSD test, $P < 0.05$). In contrast, emerald shiner and round goby found in merganser stomachs were shorter than those collected in trawls (HSD test, $P < 0.05$). Emerald shiners found in walleye stomachs were not different from those collected in trawls. The relatively minor discrepancies among the least square means shown in Fig. 2 and the arithmetic means shown in Tables 2 and 3 were due to the large discrepancy in sample size among the three sources.

Although walleye consumed a broader range of lengths of gizzard shad, there was considerable overlap in the proportions of the size classes consumed by mergansers and walleye (Fig. 3). The distribution of the total lengths of emerald shiner and round goby reflected the differences in the means from the three sources (Figs. 4, 5). Walleye consumed emerald shiners up to 140 mm total length. In contrast, less than 10% of the emerald shiners found in merganser stomachs had a total length >70 mm. Similarly, most of the round gobies found in walleye stomachs were longer than 80 mm, whereas less than 10% found in merganser stomachs were longer than 70 mm. The largest proportions of emerald shiners and round gobies consumed by mergansers had total lengths between 40 mm and 60 mm.

Diet overlap, as measured by proportions of wet weight ($\alpha = 0.668$) and relative abundance ($\alpha = 0.663$) of prey, between mergansers and walleye was significant. However, diet overlap was not significant for frequency of occurrence ($\alpha = 0.266$). This was due, in part, to the large proportion walleye stomachs that contained alewife and the absence of alewife from the merganser stomachs.

DISCUSSION

Our results for mergansers were similar to those reported by Cottam and Uhler (1937) who found that mergansers from different North American sites fed primarily on minnows (Cyprinidae), sticklebacks (Gasterosteidae) and killifish (Cyprinodontidae), but included a variety of fish. Similarly, prey of piscivorous birds sampled in freshwater from northeastern North America was composed of mostly minnows, white suckers (*Catostomus commersoni*), sticklebacks and killifish (Cairns, 1998). Hebert and Morrison (2003) estimated Lake Erie mergansers' diet composition using food habit data from Michigan stream diets (Leonard

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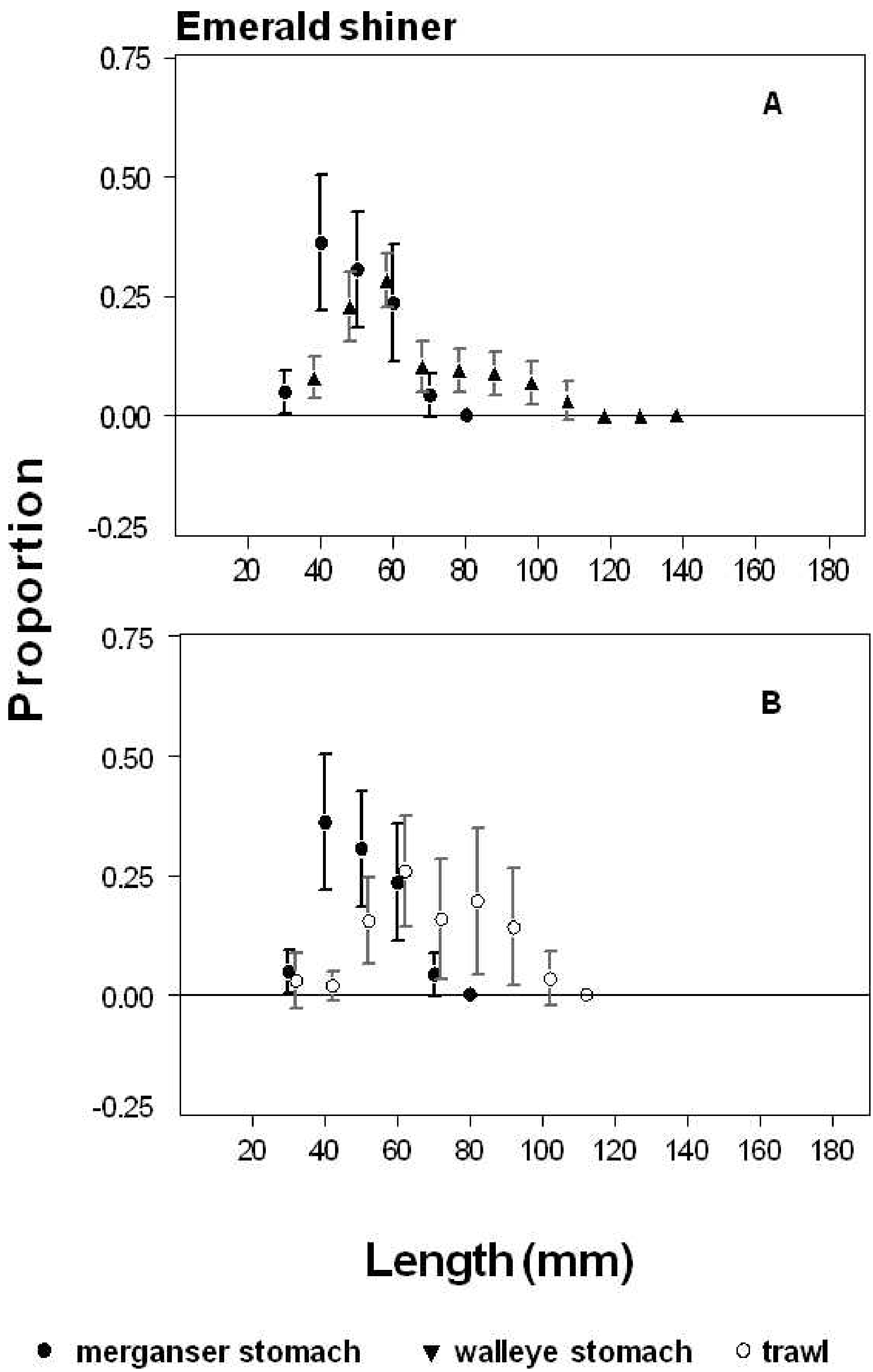
FIG. 3.—Length distributions (95% confidence intervals of total length classes in 10-mm increments) of gizzard shad found in stomachs of red-breasted mergansers, stomachs of walleye and collected from trawl catches in 1998–2000 from Sandusky Bay and adjacent waters of Lake Erie (A = gizzard shad total length distributions from merganser and walleye stomachs and B = gizzard shad total lengths from merganser stomachs and trawl catches). Negative values on the ordinate were provided only to illustrate symmetry of the confidence intervals


Emerald shiner
A
B
Proportion
0.75
0.50
0.25
0.00
-0.25
20
40
60
80
100
120
140
160
180
Length (mm)
merganser stomach
walleye stomach
trawl

and Shetter, 1936) and fish abundance data from Ohio (ODNR, 1997) and New York (New York Department of Environmental Conservation, 1996). Their consumption estimates, which differed from the present study, identified that major food items by weight were emerald shiners (30%), white perch (*Morone americana*) (20%), walleye (13–15%), invertebrates (13%) and freshwater drum (*Aplodinotus grunniens*) (10%). In our study emerald shiners made up only slightly more than 4% of the diet by weight, which was less than the respective percentages of gizzard shad and round goby. The only other common food items were white perch and zebra mussel, both of which made up <1% of the prey biomass. The source of the zebra mussel was unknown, but it may have been from either the digestive tract of a fish that was consumed or was ingested during capture of a fish on the bottom.

Walleye, freshwater drum and invertebrates were abundant in western Lake Erie (ODNR, 1999, 2000, 2001), but were not found in merganser stomachs in this study. Possible sources of discrepancies with Hebert and Morrison (2003) may be that their study area included Lake Erie proper, whereas this study sampled a much smaller segment of Lake Erie. Further, their estimates are based on winter fish consumption by mergansers in Michigan streams and autumn prey abundance from Lake Erie trawl catches. Finally, considering the total length of prey fish consumed in this study (maximal total length = 160 mm), most walleye and freshwater drum would be longer in autumn than the largest fish consumed.

Our results suggest that the diets of mergansers and walleyes overlapped significantly as measured by proportions of wet weight and relative abundance of prey but not as measured by frequency of occurrence. Wallace (1981) concluded that no single measure is adequate for comparing the diets of two species. However, percentages of volume (weight) were found to have the fewest shortcomings when calculating diet overlap.

We found, as hypothesized, that mergansers and walleye differed in the size of fish consumed. Our results suggest that mergansers are likely opportunistic foragers and that they might be limited as to the size of prey they consume. Specifically, mergansers consumed emerald shiners that were, on average, smaller than reported in trawl catches in adjacent areas of Lake Erie. These findings were similar to those for the opportunistic double-crested cormorant which also forages on western Lake Erie (Bur *et al.*, 1999). Further, Latta and Sharkey (1966) found that captive common mergansers (*Mergus merganser*) showed a preference for smaller trout over larger ones. Sjöberg (1988) found that, when satiated, two mergansers reared in captivity consumed smaller sized prey.

Our results suggest that although mergansers were capable of consuming gizzard shad that were 140 mm and longer, only a small proportion of the emerald shiner and round goby found in merganser stomachs were longer than 70 mm. This may have been due in part to behavioral differences between the two predators. The mergansers' relatively thin bill (mean culmen depth = 13.0 mm and mean bill length = 54.7 mm) may enable them to more effectively prey on small round gobies that occurred on or among the dreissenid mussels on the substrate. White (1957 and references therein) observed that mergansers will

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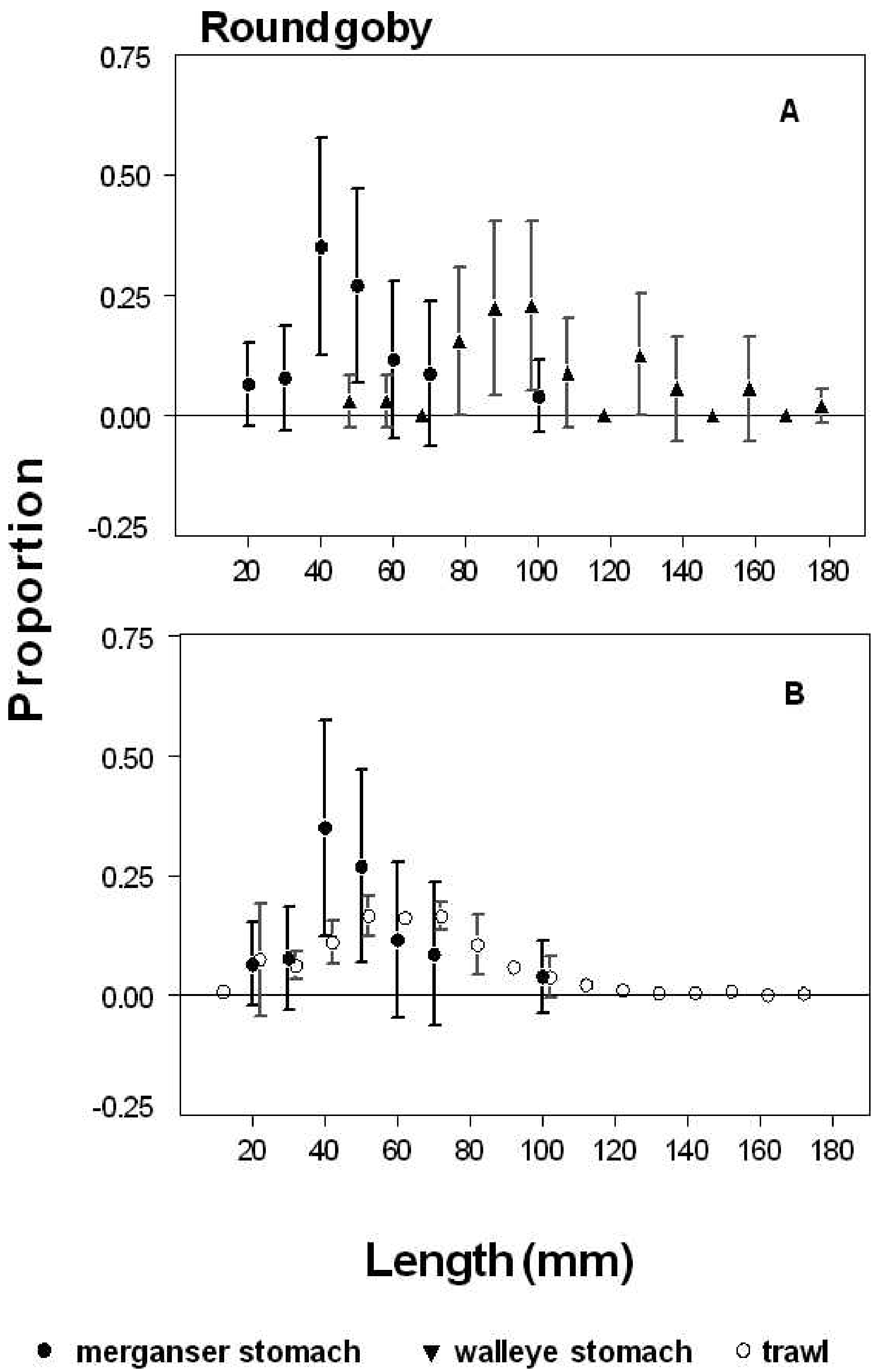
FIG. 4.—Length distributions (95% confidence intervals of total length classes in 10-mm increments) of emerald shiner found in stomachs of red-breasted mergansers, stomachs of walleye and collected from trawl catches in 1998–2000 from Sandusky Bay and adjacent waters of Lake Erie (A = emerald shiner total length distributions from merganser and walleye stomachs and B = emerald shiner total lengths from merganser stomachs and trawl catches). Negative values on the ordinate were provided only to illustrate symmetry of the confidence intervals


Round goby
A
B
Proportion
0.75
0.50
0.25
0.00
-0.25
20
40
60
80
100
120
140
160
180
Length (mm)
merganser stomach
walleye stomach
trawl

search the shallows and probe beneath stones with their bills in search of prey. Foraging behavior studies are suggested to test this hypothesis.

On average, walleye consumed longer gizzard shad than mergansers and both mergansers and walleye ingested larger gizzard shad than those captured from trawls. The morphological shape of a gizzard shad renders it a somewhat slow moving fish (Moyle and Cech, 2003), such that foraging mergansers could selectively prey upon larger individuals. Supporting evidence for this theory was presented in a laboratory study, which established that famished mergansers ate a higher proportion of larger fish when offered two different size classes (Sjöberg, 1988). Our results suggest that although walleye and mergansers consumed the same species, mergansers generally consumed smaller fish than walleye. Previous studies have offered evidence that the largest prey fish taken by a predator has a maximal body depth equal to the width of the predator's mouth (Lawrence, 1958; Johnson, 1969; Schramm and Zale, 1985; Hambright, 1991). Although we did not measure the width of the mergansers' mouth, walleye mouths are much wider. Further, bill length and culmen depth measurements would suggest that mergansers are not able to consume prey fish as large as many walleye are capable of consuming. There is, however, an upper limit to prey size that walleye ordinarily consume (Forney, 1976; Knight *et al.*, 1984), which is probably smaller than the maximum determined by its mouth size. Behavioral factors (*e.g.*, prey species' speed and ability to avoid predators and prey handling by predator) (Brown *et al.*, 2006), external structures (*e.g.*, spines) of prey (Mauk and Coble, 1970; Weithman and Anderson, 1977; Gillen *et al.*, 1981), as well as size of prey and mouth size of piscivores influence this upper limit. Based on the equations of Knight *et al.* (1984), the maximal total lengths of clupeids (including alewife and gizzard shad) for the average- and maximal-sized walleye in our study were 119.4 mm and 150.5 mm, respectively. Similarly, the maximal total lengths of soft-rayed fishes (including emerald shiners) were 144.5 mm and 188.4 mm. The means for clupeids found in walleye stomachs in our study were roughly equivalent. However, the emerald shiners found in walleye stomachs were considerably shorter than the estimated maximum. Further, our results suggest that, at least for some species, walleye and mergansers differ in the average size of prey consumed.

Although it has been suggested by commercial and sport fishers that both mergansers and cormorants can appreciably reduce the abundance of prey fish for walleyes, evidence suggests the contrary. Our results suggest that walleye eat much of the same prey species available in Lake Erie as mergansers and diet overlap is significant. However, competition between walleye and mergansers for prey fish is likely minimal. As evidence of this, the relative condition (weight-length relationship and fat content) of Lake Erie walleye are among the most robust in North America (Murphy *et al.*, 1990), as is walleye fecundity (Baccante and Colby, 1996). Estimates of prey fish density were calculated for western Lake Erie (Deller *et al.*, 2003), and suggest that the number of prey fish available for predator consumption are not limiting growth or fecundity of walleye. Madenjian and Gabrey (1995) estimated that transient mergansers on Lake Erie consumed approximately 4% of the

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FIG. 5.—Length distributions (95% confidence intervals of total length classes in 10-mm increments) of round goby found in stomachs of red-breasted mergansers, stomachs of walleye and collected from trawl catches in 1998–2000 from Sandusky Bay and adjacent waters of Lake Erie (A = round goby total length distributions from merganser and walleye stomachs and B = round goby total lengths from merganser stomachs and trawl catches). Negative values on the ordinate were provided only to illustrate symmetry of the confidence intervals

number of fish eaten annually by walleye, which is a major predator and a sport fish in Lake Erie. Data from this study will help make it possible to update the model by Madenjian and Gabrey (1995) if diets are collected during other periods of the year, especially during spring migration, since mergansers are migrant visitors to Lake Erie. The consumption model by Hebert and Morrison would also benefit from additional seasonal diet data.

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